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Switching Speeds in Magnetic Tapes

Abstract: Comparative measurements are reported on the switching speeds of three different magnetic tape materials, as determined by application of short field pulses of well-defined duration and magnitude. A sensitive measure of the change in magnetization is the length of applied pulse required for the peak readback signal to drop from 60 percent to 40 percent of its peak value. This pulse length was is 2.6 ns for a γ-Fe_2O_3 tape, 4.1 ns for a CrO_2 tape, and 1.4 ns for a cobalt-substituted γ-Fe_2O_3 tape.

Introduction

The continuing trend in magnetic tape storage systems is toward increased data rates, because of higher densities [for example, 3560 fr/cm (9042 fr/in.) in the IBM 3420 series] and higher relative velocities between the head and tape [as in the Ampex Terabit memory, which operates at 25.4 m/s (1000 in/s)]. The corresponding clock periods for these systems are of the order of 100 ns to 1 μs. In the past, it has been tacitly assumed that there is no practical limit to the speed at which a recording tape can be switched. With the higher data rates now being used, this assumption may not be valid, because a switching delay of only five ns may result in a five percent peak shift—a significant contribution to the total phase budget. The published literature on high-frequency effects in tape particle systems does not cover switching from one direction to the other. Birks [1] examined the ferromagnetic resonance in several ferrites, including γ-Fe_2O_3, and obtained an energy absorption peak at 3.85 GHz in an applied field of 2.52×10^5 A/m (3170 Oe). Valstyn, et al. [2] measured the resonance characteristics of several samples of γ-Fe_2O_3, obtaining a relaxation time of 0.2 ns. Because nuclear magnetic resonance is essentially a small-amplitude perturbation of a steady state of magnetization, switching times cannot be predicted from NMR data. A further source of uncertainty is the actual switching mechanism. The theoretical factors determining what kind of switching mechanism will occur have been established for the fanning mechanism [3] and for coherent rotation, buckling, and curling [4], but identification of a particular mechanism remains unreliable.

Measurement techniques

To measure the switching speeds of magnetic tapes, it is necessary to generate field pulses of well-defined durations and magnitudes up to about three times the coercivity of the tape being investigated. One approach to this problem is shown in Fig. 1. Many parallel 50-ohm delay lines were charged to a high potential through a large resistance and then discharged by a mercury-wetted reed switch through a short length of stripline. Resistors between each line and the switch were used to optimize the current waveform through the stripline. Because mercury-wetted switches close typically in less than 0.5 ns [5], it was hoped that pulses down to one ns would be achieved. In fact, the observed current risetime was about two ns, limiting the minimum pulse length to five ns. More detailed analysis showed that the reflection occurring at the mismatch between the reed switch, which had an impedance of 50 ohms, and the multiple parallel delay lines, with an impedance of about five ohms, was sufficient to explain the deterioration in the risetime. The pulse length was varied by changing the lengths of the delay lines, the maximum pulse length used being 31 ns from three-meter lengths of R/G 142B, a Teflon [6] -insulated flexible coaxial cable.

Small samples of dc-erased tape were placed under the stripline and pulsed. The resultant magnetization was then determined in a vibrating sample magnetometer. The value of this approach was restricted by the relatively long minimum pulse length and the breakdown voltage of the reed switch, which place an upper limit to the pulse amplitude. A similar set of equipment was built around a "Krytron" gas switch tube (E.G. & G. type

KN6B), which has a breakdown voltage of 8 kV, instead of the 2.5 kV typical of the mercury switch. Higher fields were thus achieved, but the mismatch and the poor minimum pulse length were unaltered. An alternative way of increasing the field strength is to reduce the width of the stripline. With this approach, however, the degree of mismatch between the pulse source and the line is increased, and the sample is so severely reduced in size that it is difficult to handle and measure magnetically.

A more effective method is shown in Fig. 2. A dc erased tape loop passes continuously under the stripline, which is pulsed at 360 pulses/s. The tape speed is high enough so that each zone of the tape is exposed to only one pulse while passing the stripline. The effect of the pulses was measured with a conventional audio read head, feeding a peak-reading voltmeter through a low-pass filter. Since the geometry of the stripline does not fit the usual assumption of negligible thickness (compared with its width), the actual impedance was calculated from the corrected formula [7]

$$Z_0 = \left(\frac{\mu_0}{\epsilon_0}\right)^{\frac{1}{2}} \left\{2 + \frac{b}{h} + \frac{1}{\pi} \cdot \frac{d}{h}\left[1 + \ln\left(1 + \frac{2h}{d}\right)\right]\right\}^{-1},$$

where b is line width, d is line thickness, and h is insulator thickness. For the γ-Fe_2O_3 tape on a 38.1-μm polyester substrate, and 190.5-μm copper stripline 25.4-μm thick on a 25.4-μm polyimide substrate, the line impedance is 47 ohms. The stripline is terminated in attenuators preceding a monitoring oscilloscope. The experimental procedure is to vary the pulse width by changing the delay line, keeping the pulse current constant, and to observe the resultant read signal. With the stripline geometry used, the magnetic fields are not uniform in the vicinity of the tape, and therefore only an approximate relation between the pulse current and the field magnitude can be given. The constancy of the pulse amplitude, for pulses ranging from 1 to 31 ns, was checked with a Tektronix 519 oscilloscope with a risetime of 0.29 ns and confirmed with a Tektronix 7904 sampling oscilloscope.

Results

The change in magnetization in γ-Fe_2O_3 was measured on the multiple-line pulse system with samples of ac-demagnetized tape. The change in magnetization caused by pulses of constant amplitude was not affected by reducing the pulse length from 30 ns to 5 ns. The experiment was repeated with several pulse amplitudes to generate the initial magnetization curve. No difference was observed between the low-frequency curve and the pulsed curve; any delay must therefore have been less than five ns. When the experiment was repeated with samples of chromium dioxide tape, the same result was

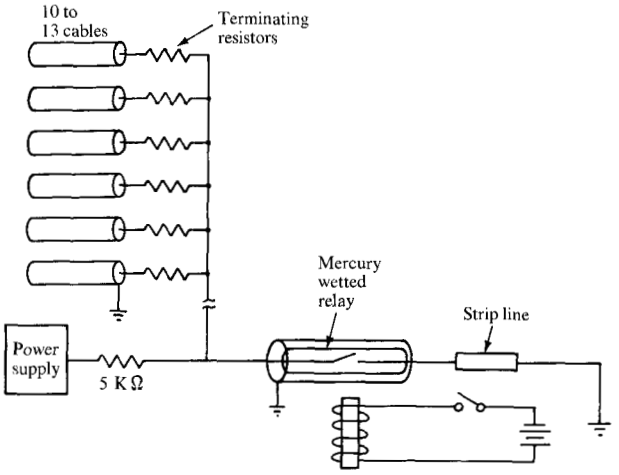

Figure 1 Circuit of parallel delay line pulse system. The values of the terminating resistors are 82Ω for pulse widths from 30 ns to 13 ns and 240Ω for pulse widths from 7 ns to 5 ns.

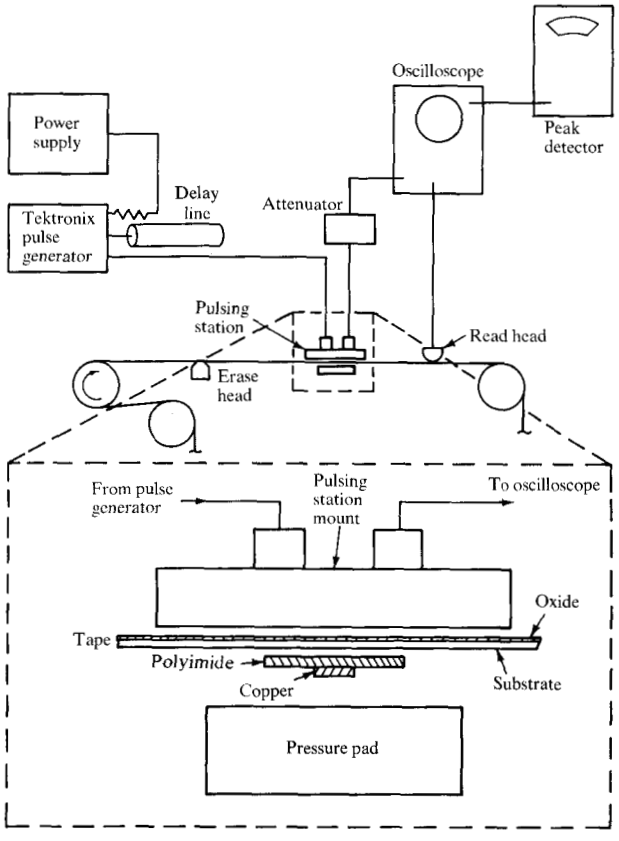

Figure 2 Diagram of the continuously pulsed tape loop system.

obtained for pulses down to 10 ns. With pulses shorter than 10 ns, the resultant magnetization was significantly reduced. Difficulties in establishing the effective pulse length prevented accurate measurements of the reduction.

Measurement of the influence of the pulse length on the peak amplitude of the readback signal were made on

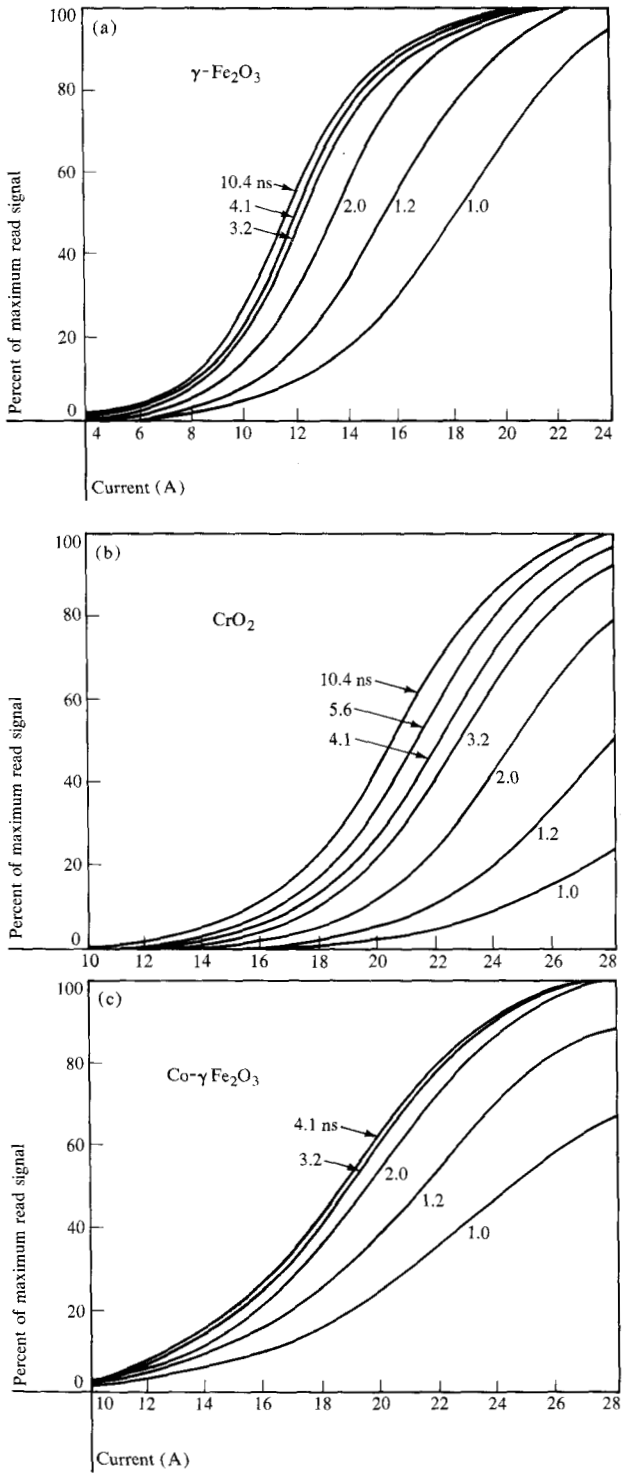

Figure 3 Read signal as a function of pulse length and write current for (a) a γ-Fe_2O_3 tape ($H_c = 2.3 \times 10^4$ A/m (290 Oe)); (b) a CrO_2 tape ($H_c = 3.8 \times 10^4$ A/m (490 Oe)); (c) a Co-substituted γ-Fe_2O_3 tape ($H_c = 4.6\ 10^4$ A/m (590 Oe).

the tape loop system of Fig. 2. The results are shown in Figs. 3, (a), (b), and (c) for tapes of γ-Fe_2O_3, CrO_2, and Co-substituted γ-Fe_2O_3, respectively. On the γ-Fe_2O_3 tape, no effects were observed until the pulse length was reduced to 5.6 ns, after which the amplitude of the read signal started to fall off. As was expected, the amplitude could be restored by increasing the amplitude of the write current pulses. Similar effects were observed on the CrO_2 tape, starting at 10.4 ns, and on the Co-substituted γ-Fe_2O_3 tape, starting at 4.1 ns. To compare quantitatively the response of the different tapes, the pulse length was noted for which the read signal decreased from 60 to 40 percent of its maximum amplitude. This decrease occurred at 2.6 ns for γ-Fe_2O_3, at 4.1 ns for CrO_2, and at 1.4 ns for Co-substituted γ-Fe_2O_3. These results support the data from the parallel-line pulse equipment, in particular the finding that the CrO_2 tape responded significantly more slowly than the others.

Conclusions

The various recording media showed marked differences in their responses to very short pulses of magnetic field. Designers of future systems featuring high data rates will have to recognize the importance of switching speed when selecting a recording medium.

References and note

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